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METHOD USED ON CHINESE CH'ANG-CH'UN RAILWAY TO DETERMINE STANDARD STOPOVER AND LAYOVER TIMES FOR CARS IN STATIONS

[Comment: This report gives the full text of an article by Sun Shu-ch'eng in the Jen-min T'ieh-tao (People's Railways), Vol III, No 6, 1951, explaining the method used on the Chinese Ch'ang-ch'un Railway to determine standard stopover and layover times for cars in stations. Terms explained in the article are represented in equations and formulas by abbreviations of the translated term.]

A. Importance of Standards for Time Cars Spend in Stations

The time that cars spend in stations is a factor of great importance in car turnaround time and in car utilization. For example, according to the method of calulation in use at first, in a certain year and in a certain territory, the car turnaround time was 3.7 days. The data available showed that a little less than one third of this time was travel time, and a little more than two thirds of it was time spent in stations for loading, unloading, marshaling, servicing, or just waiting. Consequently, it can be seen that the rational and scientific determination of standardized times for cars to spend in stations may be of decisive significance in shortening turnaround time and in the accomplishment of railway transportation tasks. Since the condition of the locomotives, and of the lines, places certain limitations on substantial increases in the running speed of trains, the shortening of the time spent in stations is the principal, if not the only, way to raise transport efficiency and increase the number of cars that may be loaded in a definite time.

The determination of standards for the time cars should spend in stations is an important element in the technical index of car utilization; that is, the standard times for cars to spend in stations is to be set rationally and scientifically, on the one hand, taking into account actual technical conditions, and, on the other hand, taking into account the energy of the workers required to

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accomplish a possible and appropiate quota of work. To stimulate productive output, it is essential to develop the activity of the workers and create conditions conductive to progress.

In the past, the usual method of determining the allowable time to be spent by cars in a particular station was to note the time ordinarily consumed in processing the cars, the type and quantity of equipment, the number and efficiency of the freight handlers, and the possibilities of improvement, and then to set a figure. This method was not very exact; it was difficult to analyze the successive procedural steps, and the method did not readily indicate places where improvements could be made. Since the Chinese Ch'ang-ch'un Railway went into operation, and with past experience as a basis, the advanced experience of the Soviet Union was brought to bear on the problem and a new method of determining standard stopover and layover periods for each particular station was set up. The new method took into account the train connections prescribed by the time tables, the order of the various steps in the process of train and car handling, and the time required for each successive step. In general correctness and in preciseness, the new method is a step in advance over the old method.

B. Determination of Standard Stopover Times for Through Cars

The time that cars spend in stations may be divided into two parts. Part one is the time spent in switching stations and is called stopover time. Part two is the time spent in the stations of origin or destination and is called layover time. Stopovers are of two kinds: (1) time spent by cars on a through train when the train stops for change of locomotives and/or for minor servicing of the locomotive or cars, but without rearrangement of the cars in the train; and (2) time spent in a switching station or marshaling yard where the train stops for rearrangement of the cars as well as for servicing. Separate computations should be made for these two kinds of stopover time.

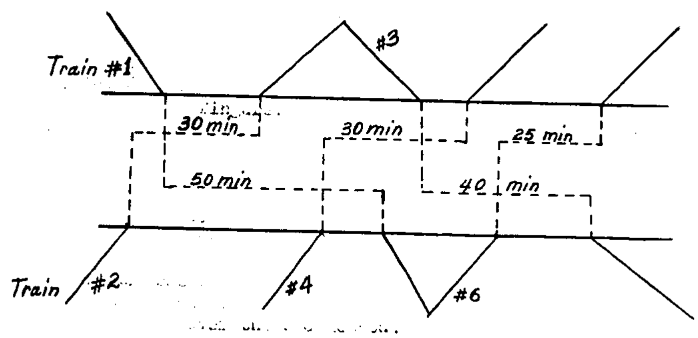
1. Cars Not Rearranged in Trains

For the cars in through trains that pass through a division point, marshaling station, or junction point, and stop only to change locomotives or for servicing of locomotive and cars, but without rearrangement of the cars, the determination of the standard stopover time for a particular station (STOVT-1) should take into account the number of trains that pass per 24-hour day, the number of cars in the trains, and the stopover times of the trains.

$$\text{STOVT-1} = \frac{\text{Number trains x number cars x stopover times}}{\text{Number trains x number cars}}$$

In this formula, the number of trains is the number regularly scheduled to pass through a particular station in a 24-hour period; the number of cars is the number regularly assigned to each train; and the stopover periods are the times each train has to spend in the station, generally depending on train schedules. The numerator is the total stopover time, in minutes, of all the cars in all the trains concerned; the denominator is the total of all the cars in all the trains. The quotient will be the average standard car stopover time.

To illustrate: With repsect to a particular station, assume that three trains pass on the up run and two trains on the down run, as shown in the following diagram, and that the number in each train and the stopover time for each train are as shown in the table below.



Direction	Train Numbers	No of Cars in Trains	Stopover Times of Trains (min)
Up	2	45	30
Up	4	45	30
Up	6	45	25
Down	1	40	50
Down	3	40	40

These figures should be put in the formula as follows:

$$\text{STOVT-1} = \frac{2 \times 45 \times 30 + 1 \times 45 \times 25 + 1 \times 40 \times 50 + 1 \times 40 \times 40}{3 \times 45 + 2 \times 40}$$

$$= \frac{2{,}700 + 1{,}125 + 2{,}000 + 1{,}600}{135 + 80} = \frac{7{,}425}{215} = 34.5 \text{ minutes} = 0.58 \text{ hour}$$

This figure for standard car stopover time should be determined each month according to the number of through trains per day scheduled for the month. If the assigned number of cars per train varies for the same train in different sections of the territory, so that some cars have to be dropped or picked up at a division point or other marshaling yard, the stopover time for such cars should be calculated by the method applicable to trains when there is rearrangement of cars.

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2. Cars Rearranged in Trains

The determination of the standard stopover time for cars that are to be rearranged in trains at switching stations [STOVT-2] should take into account two elements: (a) the time required for make-up and breakup of trains, servicing of locomotives and cars, inspections, etc., [TRSERVT (train servicing time)]; and (b) the time spent by assembled cars waiting for dispatch by the next suitable train [net WADT (waiting dispatch time)].

STOVT = gross WADT = TRSERVT + net WADT.]

a. Train Servicing time will depend on the work hours at the station and the tasks that have to be carried out. Among these are the following:

(1) Procedures relating to the arrival of trains in the station, such as inspection of the technical conditions of the cars, inspection of the conditions of the freight itself, and copying down the serial numbers of the cars.

(2) Breaking up the trains.

(3) Making up the trains, including all shunting required for breaking up and making up the trains.

(4) Procedures relating to the dispatch of trains, e.g., in regard to cars and cargo.

Each of these time components depends on the condition of the station's facilities and the size and technical skill of the working force, based partly on the past statistical data and partly on current observation. Each should be stermined with care and accuracy.

b. Gross waiting dispatch time is based on the traffic level, i.e., on the total number of cars in trains requiring rearrangement planned to pass through the station in any addition in any direction in 24 hour [NCWR]; and the average number of cars regularly assigned to the trains that pass the station [ANCPT (average number of cars per train)]. This data should be put in the following formula:

$$\text{Gross WADT} = \frac{10 \text{ (a certain coefficient)} \times \text{ANCPT}}{\text{NCWR}} \qquad [F]$$

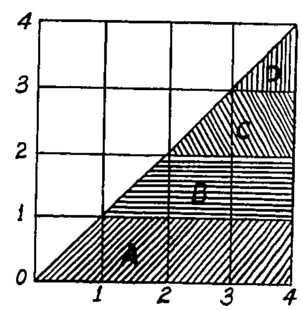
This formula may be explained as follows

(1) Gross waiting time means the time spent in the station by cars that have arrived from various places and by various lines but are destined for the points on the same line out of the switching station and are waiting until a sufficient number have been assembled to make up a train to take them on their journey, or are waiting for the next regular through train to which they may be attached. For instance, a number of cars reach the Harbin station from points on the Harbin--La-lin, Harbin--Pei-an, Harbin--Man-chou-li (Lu-pin), and Harbin--Sui-fen-ho lines, all of which are bound for points on the Harbin--Ch'ang-ch'un line. These cars arrived in Harbin at different times and hence have to wait different lengths of time until they are formed into or attached to a train to Ch'ang-ch'un. These circumstances are among those with a bearing on waiting time.

(2) The number of cars and the length of time they have to wait for dispatch on the Ch'ang-ch'un line affect the number of trains to be dispatched and hence the interval between trains. For example, assume that in a 24-hour period six freight trains are dispatched from Harbin to Ch'ang-ch'un; then the interval between trains would be 4 hours, and the waiting time for cars would not exceed 4 hours for any car, and might be much less for some cars. If there were eight trains a day, the waiting period would be 3 hours at most. At the same time, the number of trains to be dispatched on this run is influenced not only by the number of cars to be handled but also by the facilities on the run, such as the number and power of the locomotives available, the characteristics of the line, and other traffic using the same line.

In general, however, the volume of traffic in a 24-hour period, expressed in terms of the number of cars assembled at one station and awaiting movement on a common line, divided by the assigned number of cars per train will indicate the number of trains required. Thus, if 240 cars in one day reach Harbin from various places all bound for points on the Ch'ang-ch'un line, and if each train is supposed to haul 40 cars, then six trains will be needed. Hence, the number of cars to be moved and the assigned number of cars per train constitute the second set of factors that affect the waiting time.

(3) Bearing in mind the circumstances and factors mentioned just above some of which are variable and some set, it may be stated, theory and practice agreeing, that the average waiting time is about 50 percent of the interval between trains on the run on which the said cars are to be transported. Thus, if there is a train every 4 hours, the waiting time for switched cars will average about 2 hours. The following diagram illustrates why this is so.



Vertical figures represent hours elapsed since departure of last previous train. Horizontal figures represent the hours till next train. Shaded areas indicate waiting time.

Area A represents 3 1/2 hours' average waiting time for the cars that arrive during the first hour following the departure of a train. Area B represents 2 1/2 hours' waiting time for those cars that arrive during the second hour; C, 1 1/2 hours for those cars that arrive during the third hour; and D, 30 minutes' waiting time for the cars that arrive during the fourth hour. The average of these is 2 hours.

Note: If the arriving trains do not arrive uniformly throughout the intervals between departing trains, this might affect the duration of the average waiting time. However, when train schedules are made up, they should be arranged so that the arrivals of trains at switching stations are fairly evenly distributed throughout the day and night so as not to increase the average waiting time, and what is more serious, not cause congestion or even a blockade.

(4) While it has just been stated that the gross waiting time of cars to be switched in switching stations is about 50 percent of the interval between trains on the same run, there are two other points to be considered.

(a) Part of the time from a train's arrival at a switching point until the departure of the train that is to haul the cars to their destinations is the necessary train servicing time, which is separately calculated as a matter of course, and hence train servicing time should be deducted from the gross waiting time to get the net waiting time.

(b) The above calculations were made on the basis of general conditions. But when train schedules are being made up, it is desirable, as far as possible without affecting the rational organization of the train servicing work of a station, to endeavor to have as little time as possible elapse between the arrival of cars at a switching station and their departure after switching. Congestion and crowding should both be avoided.

A consideration of the current operational conditions on the Chinese Ch'ang-chun Railway indicates that about 17 percent should be deducted from the gross waiting time calculated as above, to cover the train servicing and switching time.

(5) Having explained the above points, it is now possible to show how the formula for net waiting time [F] mentioned above is derived.

$$\text{WADT} = \frac{24\,(\text{i.e., No of hours a day})}{\frac{\text{NCWR}}{\text{ANCPT}}} \times \frac{50}{100} \times \left(1 - \frac{17}{100}\right)$$

$$= \frac{24 \times \frac{50}{100} \times \frac{83}{100}}{\frac{\text{NCWR}}{\text{ANCPT}}} = \frac{9.96 \times \text{ANCPT}}{\text{NCWR}} \qquad [F]$$

To secure a round number, fractions less than 0.5 are dropped; if more than 0.5, the next larger value is taken e.g., 9.96 becomes 10. Hence:

$$\text{WADT} = \frac{10 \times \text{ANCPT}}{\text{NCWR}} \qquad [F]$$

Note: the use of 10 in place of 9.96 as coefficient in the formula serves here to illustrate the reasoning by which the formula was derived. Actually, because of varying conditions in different switching stations, the coefficient should be empirically determined for each station if it is found that 17 percent deduction for switching and train servicing time does not fit every case.

The determination of net waiting time should be computed separately for each intersecting line at a station, since the number of trains per day and hence the intervals between trains are not the same on all lines.

Suppose the switching circumstances at the Ch'i-ch'i-ha-erh station are as follows: For cars to be dispatched in the direction of Ang-ang-ch'i, the number of cars requiring arrangement is 150; the number of cars assigned per train is 45. The the net waiting time is:

$$\text{WADT} = \frac{10 \times \text{ANCPT}}{\text{NCWR}} = \frac{10 \times 45}{150} = 3.0 \text{ hours}$$

For cars to be dispatched in the direction of Ning-nien:

$$\text{NCWR} = 40 \text{ cars; ANCPT} = 30 \text{ cars;} \quad \text{WADT} = \frac{10 \times 30}{40} = 7.5 \text{ hours}$$

For cars to be dispatched on the Pai-ch'eng-tzu line:

$$\text{NCWR} = 180 \text{ cars: ANCPT} = 45 \text{ cars;} \quad \text{WADT} = \frac{10 \times 45}{180} = 2.5 \text{ hours}$$

Accordingly, the weighted average net waiting time for cars at the Ch'i-ch'i-ha-erh station is:

$$\text{Average WADT} \ \frac{\sum \text{car-hours spent in waiting}}{\sum \text{number of cars involved}}$$

$$= \frac{10 \times 45 + 10 \times 30 + 10 \times 45}{150 + 40 + 180} = \frac{1,200}{370} = 3.24 \text{ hours}$$

If the time for servicing trains at Ch'i-ch'i-ha-erh is as follows: arrival procedures, 15 minutes; breakup of train, 35 minutes; make-up of train, 30 minutes; departure procedures, 20 minutes; average waiting time, 3.24 hours, or 194.4 minutes; then the standard stopover time at Ch'i-ch'i-ha-erh for cars in trains that have to be rearranged is:

$$\text{STOVT-2} = 15 + 35 + 30 + 20 + 194.4 = 294.4 \text{ minutes} = 4.9 \text{ hours}$$

3. The standard stopover time at a particular switching station for cars in trains some of which are to have their cars rearranged and some of which are not to have them rearranged (STOVT-B, combining the conclusions of sections 1 and 2 above) is found as follows: multiply the number of cars in trains not to be rearranged (NCNR) by the stopover time that applies to them, add to that the product of the number of cars in trains with rearrangement and the stopover time that applies to them, and then divide the resultant sum by the combined number of cars in these two kinds of trains.

$$\text{STOVT-B} = \frac{\text{NCNR} \times (\text{STOVT-1}) + \text{NCWR} \times (\text{STOVT-2})}{\text{NCNR} + \text{NCWR}}$$

$$\text{STOVT-B} = \frac{370 \times 4.9 + 215 \times 0.58}{370 + 215} = \frac{1,937.7}{585} = 3.31 \text{ hours}$$

C. Layover Time in Stations of Origin and Destination

The handling of the freight itself sometimes takes place in one station, as when a car is unloaded in one station and reloaded in the same station; and sometimes in two stations, as when a car is loaded in one station and unloaded in another station. From the standpoint of efficiency of car utilization, reloading in the same station is preferable, since the layover time for one freight-handling operation in a station is not the same as when two operations take place in the same station, it must be separately computed.

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1. Single Freight-Handling Operation

Layover time in a station where a single operation takes place [IAOVT-S], consists of the time required for the following constituent operations:

a. Train arrival procedures.

b. Breakup of train

c. Waiting in the marshaling yard for delivery of loaded car to the platform or other point where unloading is to take place. This period of time depends on such factors as the arrangement of tracks and switches in the marshaling yard, the number of locomotives available for the shunting of cars, the method and ability of the yardmen, and the type, capacity, and relative location of loading and unloading facilities. These factors all have a bearing on what is referred to as technical work on cars.

d. Delivery of cars from the waiting track in marshaling yard to the unloading point, i.e., putting the car in position, whether within the yard limits or on a special-use spur track. The time required for this purpose depends to some extent on the distance involved and other technical factors.

e. Loading time or unloading time, as the case may be. The time required for these operations depends on such factors as whether the cargo is bulk or packaged; the size, weight, and number of pieces; how the cargo is loaded or to be loaded or stowed; fragility; and whether the cargo is to be loaded manually or by mechanized equipment. The time required for these operations must not be greater than the standard allowed by the railway administration for loading or unloading operations.

f. Waiting, after loading or unloading operations have been completed (factors are similar to those in c, above).

g. Collection of loaded or unloaded cars and placing them in the marshaling yard (Factors are similar to those in d above).

h. Assembly of cars.

i. Marshaling into trains to be dispatched.

j. Train-departure procedured.

All these individual operational procedures must be carefully measured and considered for each layover station, and then combined to determine the standard layover time for a single operational layover period.

2. Double Freight-Handling Operation

The standard layover time in a station where both unloading and loading take place [IAOVT-D] consists of the time required for all of the ten operations listed for single operations, plus the time required for an additional operation, namely, the moving of a car from where it was unloaded to where it is to be loaded, unless both operations are to take place at the same place. The measurement and consideration of the time required for these 11 operations in order to determine the total standard time required for a double operational layover period must be carefully made with regard to all relevant factors listed for single operations. In some cases, the shifting of an empty car from its unloading position to its loading position may require a shunting locomotive; in other cases, the freight handlers themselves may move the car by hand.

3. Combined Layover Time [LAOVT-B] for Loading and Unloading Operations

The standard layover time for a particular station is determined by a combining the time required for single and double-operation cars as ascertained in the manner indicated above. This time is found by multiplying the number of single-operation cars by the time required for processing one such car; adding the number of double-operation cars multiplied by the time required for one such car; and then dividing the sum by the total number of loaded cars that were processed plus the number of these cars that, after being unloaded, were reloaded in the same station.

To illustrate: Suppose that, at Mu-tan-chiang station, 150 loaded cars entered the station each day with goods consigned to Mu-tan-chiang, and that 80 of these cars were reloaded in the same station. Also assume layover times in that station of 10.2 hours for a single operation and 13.5 hours for a double operation. The combined standard layover time for Mu-tan-chiang station would be:

$$\text{LAOVT-B} = \frac{(150 - 80) \times 10.2 + 80 \times 13.5}{150 + 80} = \frac{1794}{230} = 7.8 \text{ hours}$$

[Comment: Although this figure, 7.8 hours, at first may appear incorrect because it is not between 10.2 and 13.5, it should be noted that in the case of the double-operation cars the time for one operation is half of 13.5, or 6.75 hours. The reason the denominator is 150 + 80 is that all 150 cars underwent unloading and, in addition, 80 cars underwent reloading, thus making 230 single operations, some of which required 10.2 hours and some only 6.75 hours.]

4. Determination of Standard Number of Cars To Be Handled at a Station [SNCH]

Having determined the standards for stopover time in switching stations and for layover time in terminal stations, it is now possible to compute the standard number of cars to be handled in a particular station in one day, from 1800 hours of one day to 1800 hours of the following day. The standard number, in the technical sense intended here, will be computed by counting 24 car-hours as one car [-day]. In other words, the standard number of cars handled does not mean that every car that passes through a station in one day will be counted as one car, regardless of how long it was there; nevertheless, the time spent in the station by every such car, whether long or short, will enter into computation of the standard figure. The "number of cars handled," in its inclusive sense, will include all cars that arrive in or depart from the station, as well as those that make a stop and pass through with or without rearrangement of cars.

The standard number of cars handled is useful for judging whether or not the work accomplished in a station corresponds with its capacity for receiving and processing cars in accordance with technical relations. By comparing the actual number of cars handled and the amount of time actually spent in the station with the standards that have been determined for that station, it may be possible to detect weaknesses, waste, or errors, and to discover changes and improvements in procedures, methods, and facilities whereby the capacity of the station might be further developed and its performance improved. The results of such an eximation of each station should be kept in mind when transportation plans are formulated.

The standard number of cars handled in one day [SNCH] for a particular station is found by dividing the aggregate time in hours spent in the station by all cars handled by 24 (the number of hours in day). The aggregate time will consist of the sum of three terms:

a. The number of through cars in trains with no rearrangement of cars in the train [NCNR], multiplied by the standard stopover for such a car [STOVT-1].

b. The number of through cars in trains with rearrangement of cars [NCWR], multiplied by the standard stopover time for such a car [STOVT-2].

c. The number of cars arriving in and departing from the station for loading or unloading or both [NCAD], multiplied by the standard layover time for such cars [LAOVT-B]. Hence the formula is as follows:

$$SNCH = \frac{NCNR \times (STOVT\text{-}1) + NCWR \times (STOVT\text{-}2) + NCAD \times (LAOVT\text{-}B)}{24}$$

Suppose that at the Kirin station, based on the monthly transportation plans, the daily average traffic and standard time periods are as follows:

NCNR = 160	STOVT-1 = 0.6 hours
NCWR = 500	STOVT-2 = 5.2 hours
NCAD = 80	LAOVT-B = 8.3 hours

$$\text{Then SNCH} = \frac{160 \times 0.6 + 500 \times 5.2 + 80 \times 8.3}{24} = 140 \text{ car-days} = 140 \text{ cars}$$

It should be explained that this number [SNCH] is something quite different from the number of cars at a station at 1800 hours, which is customarily reckoned and reported to the bureau. The latter figure is based on the number present at that hour, regardless of how long or short a time they have been there; while the former is computed on the basis of the total number of car-hours spent by cars in the station in the course of the preceding 24-hour period, and one car is counted for every 24 car-hours.

5. Requirements for Use of This Method of Ascertaining Standard Number of Cars Handled

The methods described above for ascertaining the standard stopover and layover times and the standard number of cars handled in one day at a particular station may be used only under the following conditions:

a. The computations on the basis of which the monthly transportation plan are based must be correct and accurate.

b. All the operations performed at car or train servicing stations must be carried out in strict conformity with those regulations, approved by the bureau chief, that pertain to the various technical services and loading or unloading procedures.

c. Intermediate stations handle a comparatively small quantity of freight for loading or unloading, and the time consumed in dropping or picking up cars is quite limited. These methods therefore, are not suitable for calculating stopover and layover time for such stations.

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6. Conclusion

For stations where standards have been determined, what are the questions that then arise? Actual performance as shown in available statistical data should be analyzed in the light of the standards, in order to discover the why performance has not conformed with the standards. Proper remedial measures may then be decided on. Analysis will also show how the total stopover or layover time is affected by each step in the servicing process and by the general work organization. When a defective performance is detected, it should be investigated by the railway's technical engineer in the presence of the employees concerned, so that their explanations and suggestions may be heard, and changes made where advisable. Such an investigation may result in discovery of valuable techniques that can be passed on to other stations.

One last point: Careful analyses must be based on accurate and recent statistical data. If these are not available, then an uncompromising fight must be waged against carelessness, mistakes in calculations, fabrication of false data, and all other malpractices and inefficiency.

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